THE MYTH OF EQUAL TEMPERAMENT

By Ll. S. Lloyd

No true harmonic ideas are based on equal temperament.

Sir Donald Tovey, 'Encyclopaedia Britannica,' 14th ed. (article 'Harmony').

It often happens that the piano is the first musical instrument with which a child becomes familiar. If it interests him, its seven white keys to the octave give him his first idea of the diatonic scale. If he learns to play a little on the piano, and to use some of the black keys for scales of different pitch, he is confirmed in his idea of a scale consisting of a fixed series of "notes"; and he thinks of the intervals between successive notes as being sometimes a semitone but more frequently a whole tone, all whole tones being, to him, the same size. As his experience grows and he learns to manage the key of A major or C minor, he thinks of each of the black keys as dividing the intervals between two white keys, musically as well mechanically, into halves. He makes no distinction between G♯ and A♭, and he thinks of all semitones, diatonic or chromatic, as being exactly the same size and always half a whole tone. The notions implanted in childhood take deep root, and many of us never outgrow these early impressions; for a lifetime we continue to think of the tuning of the piano as a musical scale.

It is rather interesting to reflect that a child who was born a century or so before we were would probably have acquired a somewhat different conception. His parents' piano would have been tuned in mean-tone temperament, at any rate if he were an English child, and he would have found that A♭ in the key of E♭ major was not produced satisfactorily by playing G♯. Later, he would have been pleased to find that, on a few organs, the corresponding black key was divided, so that he could sound two separate sets of pipes; one for G♯, the other for A♭. He would certainly form an idea that diatonic and chromatic semitones are not the same size. He would think of the interval G♯—A (using different letters) as a diatonic semitone, and the interval A♭—A (using the same letters) as a chromatic one.

The musical amateur of to-day is often unaware that the tuning with which he is familiar, on his piano, became general in this country only a little more than a century ago, and is quite a modern innovation on the organ. The tuning of organs in mean-tone temperament was the rule in the first half of the nineteenth century, and our grandfathers contrasted it favourably with the new-fangled tuning. Thus, in 'The Philosophy of Music' (1879), William Pole wrote :

> The modern practice of tuning all organs to equal temperament has been a fearful detriment to their quality of tone. Under the old tuning an organ made harmonious and attractive music, which it was a pleasure to listen to. . . . Now, the harsh thirds, applied to the whole instrument indiscriminately, give it a cacophonous and repulsive effect.

All musicians know that equal temperament is an acoustical compromise, tolerated by many ears on the piano, and designed to satisfy as completely as possible three incompatible requirements —true intonation, complete freedom of modulation and convenience in practical use in keyed instruments—and that it sacrifices the first of these to the second and third. But they are not always quite so clear about the precise effect which this compromise has on the various musical intervals. This effect is illustrated in Fig 1.[1] On the right-hand side the intervals of equal temperament, applied to the scale of C, are drawn with theoretical accuracy. On the left-hand side various musical intervals are drawn with a similar theoretical accuracy, an accuracy that ignores the limitations which different pairs of human ears experience in differing degree in their estimation of those intervals in varying circumstances that occur in musical performance.[2] The tempered fourths and fifths are nearly true, but the tempered thirds and sixths are faulty. The difference between an octave and a perfectly true major seventh, or between a perfect fourth and a major third, is a diatonic semitone ; and it is obvious from the figure that the tempered semitone is appreciably less than a diatonic semitone. The difference between a major third and a major tone is a minor tone ; and the figure makes it evident that the tempered whole tone approximates more closely to a major tone than to a minor tone. (This is where it differs from the mean-tone of the old tuning which was half-way between a major tone and a minor tone, with the

(1) The writer desires to record his indebtedness to the Oxford University Press for permitting this reproduction of a figure adapted from the musical slide-rule that accompanies his booklet with that title.

(2) 'Music & Letters', Vol. XIX, p. 445, October 1938.

result that the mean-tone semitone was larger than a diatonic semitone).

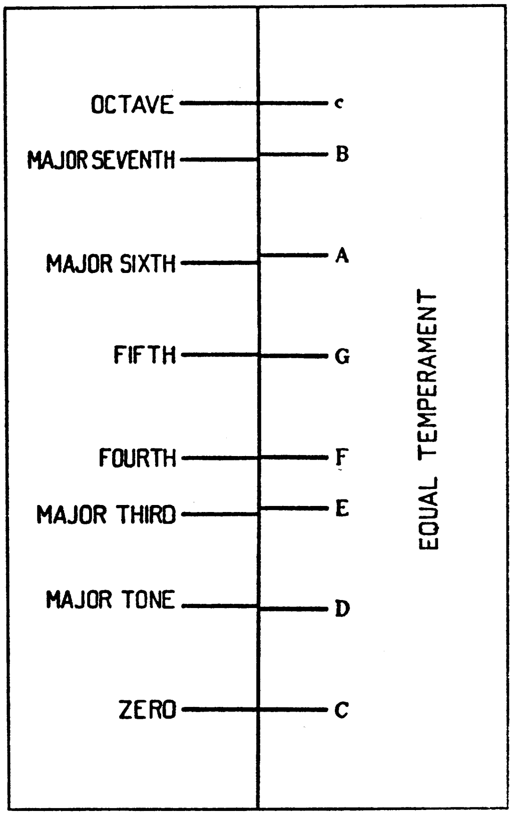

Fig. 1

Let us return, however, to our own childhood and think of the scale as we then imagined it. As we grow older a select few, gifted with great delicacy of ear, may learn to play a stringed instrument really well. Experience will teach them the truth, emphasized by Lionel Tertis in his ' Beauty of Tone in String Playing ', that to play perfectly in tune constantly calls for the most intent listening. They will know that, in a violin player, only carelessness, or lack of skill, or inattention to his faculty of hearing will explain faulty intonation. When they are told that a musical scale-system must be a flexible thing if all concords are to sound in tune they will say : " Perfectly true ! " They will appreciate also the license enjoyed in the intonation of decorating notes which do not form an

essential part of the prevailing harmony.[3] The idea that the estimation of musical intervals, by the ear, varies in accuracy with the musical occasion[2] may or may not interest them, but they will not boggle at it. They will be conscious of something not quite satisfactory in the tuning of the piano. They will be sure that there is something wrong about the tuning of a harmonium or a chamber organ.

Others of us again, not so fortunately endowed by nature, may turn to the study of counterpoint. As we make ourselves familiar with the music of Palestrina and our English Tudor composers we find, as Stanford told us we should, that we are beginning to think in the pure scale[4] of sixteenth-century polyphony and to hear, with our mind's ear, ideal singers singing perfectly in tune. A scale consisting of intervals becomes the most natural thing in the world, and when Stanford explains to us why the pure scale must be a flexible thing if intonation is to be true we at once accept his statement. We shall be amused or irritated, in varying degree, by those who imagine that music has any use for the so-called "just intonation" which was confuted by Dr. Murray Barbour in an article he contributed to the issue of this journal for January 1938, a "tuning" for which a more logical and descriptive name would be "just temperament".[5]

Others of us may happen to read, in books on sound as a branch of physics, of the vibrations of sounding bodies which we perceive as musical tones. We learn to calculate, as a matter of arithmetic, the ratios between two rates of vibration which produce familiar musical intervals. We accept the results of laboratory experiments, made perhaps with sirens, as fixing these ratios ; and thus far, but no farther, we bring the ear into the picture. Now this is quite the proper approach to the problem of tuning keyboard instruments, for the tuner's procedure is to estimate the rate of beating which produces the appropriate degree of mistuning required for equal temperament. The problem of tuning is, essentially, one of physical acoustics. The knowledge we may thus have gained does not equip us, however, to deal with the misconceptions of "theoreticians"[6] who proceed to make other calculations, about the

(3) "An animated intonation [on the violin] is no more mathematically true than an animated time-keeping is strictly according to the metronome." Moritz Hauptmann, 'Letters', quoted in 'Music & Letters', Vol. XIX, p. 443, October 1938. Hauptmann objected to the piano, as an instrument to accompany his violin, not because of its *faulty* intonation, but because of its *rigid* intonation.

(4) C. V. Stanford, 'Musical Composition', pp. 13–17. It is one of the minor offences of the "theoretician" that he confuses the pure scale of sixteenth-century counterpoint with "just temperament".

(5) 'Music & Letters', Vol. XX, p. 371, October 1939.

(6) See page 361 and footnote 24.

vibrations corresponding to musical tones we hear, which leave out of account the ear's power of estimating musical intervals in varying musical circumstances.[2] Assuming the " theoretician " to know more science than we do, and that the printed word must surely express accepted authority, we are troubled when we are told that the music of the last two hundred years rests on a false foundation because (as the " theoretician " alleges)[7] it was composed in equal temperament, or that equal temperament is implied in enharmonic change,[8] or that the twelve-note semitonal scale of modern composers can only be explained by equal temperament. We reach the conclusion that there is some sort of conflict between science and music, and we decide that here are unfathomable mysteries and that it will be best to stick to music.

'The Musical Times' for December 1939 contains a short article which is so apposite to our theme that it might have been specially written to illustrate it.[9] By the kindness of the author, and the courtesy of the Editor of that journal, I am able to reproduce a part of what he says and the first two musical examples he quotes from Bach :

> The more one studies Bach, the more incredibly fine his " linear " writing—to use a modern phrase—appears. Take every line separately and each seems absolutely right ; put them together and they seem righter still. . . . How often is the full harmonic richness of the following [Fig. 2] appreciated ? Bach enjoyed it so much that he repeated it three times in different keys :

Brandenberg Concerto No. 1, Slow Movement

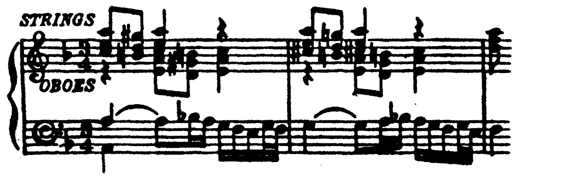

Fig. 2

> And then there is this [Fig. 3] (a fine thing, spoilt in Mendelssohn's edition—perhaps not deliberately—by the substitution of C♮ for C♯) :

(7) 'Music & Letters', Vol. XIX, p. 447, October 1938.

(8) " Enharmonic modulation . . . is popularly supposed to belong specially to tempered scales ; but it really presupposes just [*i.e.* true] intonation."—Sir Donald Tovey, 'Encyclopaedia Britannica', 14th ed. (article 'Harmony').

(9) 'Musical Times', No. 1162, p. 795, 'An Aspect of Bach', by H. Ian Parrott.

'CHRISTE, DU LAMM GOTTES' ('ORGELBÜCHLEIN')

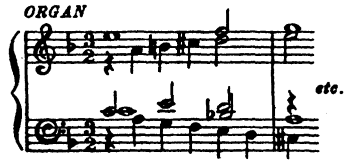

Fig. 3

> I feel that there is hardly a single composer since Bach who has not been foreshadowed in some way by him. And it is the number of comparatively *recent* composers which makes this fact the more remarkable.

The author advances a suggestion that is wholly convincing for, when pointed out, it leaps to the eye : that recent composers hark back to Bach because they write polyphony and are not afraid of dissonance. But the whole article invites the attention of readers of this journal ; and because it is so musicianly the acoustical science implied in it is unimpeachable.

Let us examine the clash between B♮ and B♭ in the first example. Here we are surely harking back to music of an earlier period than Bach's ; to music written before temperaments were invented. This is what the Editors of 'Tudor Church Music' say about the scale-system of Taverner's day (first quarter of the sixteenth century) : [10]

> If a modern musician is asked to think of the key of D, his mind will probably construct a framework consisting of two Ds, an octave apart, with a set of six notes between. In Tudor times this point of view had not been reached. Scales were then governed by the hexachordal system, which, in the key of D, would comprise the hexachord D, E, F, G, A, B♭ with an extension below to C♯ and B♮, and an extension above to C. From this conception arose the fact that, whilst to us there exists a choice (when the seventh degree of the scale is required) between C♯ and C♮, to composers of the sixteenth century the notes were not alternatives but equal and substantive members of the key, with quite different functions.

Because the scale discoverable in the polyphonic music of Taverner and his contemporaries has this hexachordal basis, English composers of his day found nothing unnatural in those harmonic clashes which are a characteristic feature of their cadences. The melodic line was everything : harmony was in the making, it was being formed by writing concurrent melody. Without implying that Bach knew the music of our Tudor composers, can any

(10) 'Tudor Church Music', Vol. I, p. xlii, from which this quotation is reproduced by kind permission of the Carnegie United Kingdom Trust.

musician question whence came the scale-system discoverable in the quotation from the first Brandenburg Concerto (Fig. 2)? Bach summed up the achievements of all his predecessors, and his harmony derives from the contrapuntal procedures of the polyphonic period. Like his English predecessors, he took delight in this logical application of principles embodied in the hexachordal scale-system. He adopted a tuning for his clavichord which had first been invented more than a century before his day. But he did so because his genius impelled him to claim complete freedom of modulation. To suppose that by so doing he established a false foundation for all later occidental music is to ignore all the lessons of musical history, and to imagine that scales came first and music afterwards. Had some supreme authority abolished all keyboard instruments from the earth in the sixteenth century and ever after, composers writing for voices, strings or the orchestra would have made music from which we could distil the same flexible scale-system, with its use of enharmony, as we discover in their compositions to-day. Bach imposed no tyranny on the intonation of all later music. On the contrary he re-asserted its right to freedom of intonation, and he tuned his clavichord to express his musical imagination as well as it could. Only the " theoretician ", thinking in terms of physical vibrations and a *rigid scale*, *i.e.* a " tuning " not a musical scale, can reach any other conclusion.

Many will have heard the first-quoted bar of the Brandenburg Concerto (Fig. 2), if only on the wireless, without being uncomfortably conscious of the clash between B♭ and B♮. The contrapuntist, knowledgeable in the use of *musica ficta*, will think of the B♭ as being close to the A; of the interval in the sequence A—B♭—A[11] as being much less than a diatonic semitone; and similarly for the sequence C—B♮—C of the oboes. The string player will assume that the cellos would probably flatten the B♭; and, so far as the limited flexibility of intonation of his instrument permits, a skilled oboe player would tend to sharpen the B♮. Moreover the ear is assisted by the difference of timbre between the strings and the wind which helps it to hear the two melodic lines apart. Now try the passage on the piano: the effect in the first bar is hardly tolerable. In the middle of the keyboard B♭ has a powerful octave overtone, and the clash of physical vibrations will produce an unpleasantly harsh sensation in the ear. The " note " of the piano is lacking in acoustical definition, as compared with that of the violin or of many combinations of organ stops. There is evidence

[11] Hauptmann cites the sequence C—D♭—C to illustrate the argument quoted in footnote 3, p. 350.

that the pianist's educated aural perception, which is not that of a skilled violinist, leads him to hear the intonation of the simple concords on his instrument as something which he does not distinguish from the concords of the "pure scale"[4] But the physical clash of the tempered B♭ and B♮, struck together, will defeat the tolerant aural perception of the most complacent ear. Bach was not writing for a keyboard instrument in this Brandenburg Concerto, and musicians will agree that the "theoretician" is not entitled to assume that, in writing it, he was thinking in terms of the tuning of his clavichord.

Let us now look at the notes falling in the third crotchet beat of the first bar of Fig 2. To our modern ears the oboes are still playing a chord of A minor, while the bass has already modulated into D minor. Does this foreshadow any *prima facie* ground for assuming that what the theorist conveniently calls *polytonal* music presupposes equal temperament? The explanation which Dr. A. F. Barnes—writing as a musician—gives,[12] that music written in the modern twelve-note semitonal scale depends on the contrapuntal framework and the enharmonic latitude enjoyed, is surely more logical, and far more musicianly. It is infinitely better science.

Nor does the clash of C♮ and C♯ in the second example, Fig. 3, lead us to qualify the conclusions of the preceding paragraphs, notwithstanding the fact that the organ, with its sustained tones, may often give more acoustical definition to a note than does the piano. Observe that the C♮ is a sustained note. If we play this prelude on the organ we find satisfaction in the ruthless melodic line of the "alto", in spite of the rigid intonation of the instrument, because the sustained C♮ falls into the background of our aural perceptions. Our ears are fully occupied in attending to the two lines of melodic motion.[13] Similar examples are found in other organ preludes of Bach. For instance in the setting of 'Nun komm, der Heiden Heiland' for manuals only (Fig. 4, where marked with an asterisk):

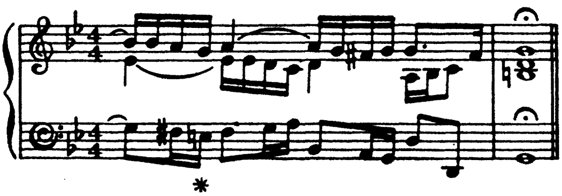

Fig. 4

[12] In 'Practice in Modern Harmony', 1937, pp. 29 and 30.

[13] Observations which are pertinent will be found in Bernard van Dieren, 'Down among the Dead Men', p. 189, and R. O. Morris, 'Contrapuntal Technique in the Sixteenth Century', p. 37.

Similarly in the organ prelude, ' O wie selig seid ihr doch, ihr Frommen ' (Fig. 5), Brahms writes :

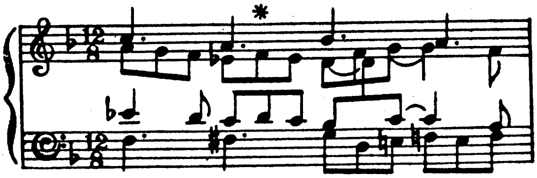

Fig. 5

These passages are written thus, not *because* of the rigid intonation of the organ (Bach's organ was tuned in mean-tone temperament), but *in spite* of it. What evidence is there in all this that composers write, as the " theoretician " supposes, in equal temperament?

Modern science gives no support to the " theoretician ". Laboratory investigations(14) show conclusively that, measured by the physical vibrations in the air, the melodic scale of the violin player (unaccompanied) is a flexible affair. In any contrapuntal writing the string player's feeling is for his linear melody ; only in a concord on the accent of the bar will his sensitive ear impel him to produce a consonance with the other strings. Helmholtz and Lionel Tertis tell the same story.(15) But this is not all. It is easy to play out of tune : it is a superhuman feat to play " off the note " with exactly the mistuning required for equal temperament, for we may be sure that the player has no physical means of reproducing equal temperament with the accuracy with which a good string quartet can play in tune. Even the piano tuner with an ear trained to measure the desired dissonance, and with ample time to listen to the beats he produces, does not tune the instrument perfectly in equal temperament.

Fig. 6 overleaf is a trace of the actual rates of vibration one tuner produced in the piano, as recorded by the Chromatic Stroboscope. This is a scientific instrument which records, instantly and accurately, the rates of vibrations that travel through the air to our ear-drums from something that produces a musical sound. The standard of reference is the nearest vibration of a perfect tuning in equal temperament of international pitch (A=440). The rates of vibration which produce perfect equal temperament are represented by the vertical line down the centre of the figure. A vibration which is too sharp for perfect equal temperament is marked by a point to the right of that line : one which is too flat

(14) The most recent are those of P. C. Greene, ' J. Acoust. Soc. Amer.', 1937, **9**, 43.
(15) ' Music & Letters ', Vol. XX, pp. 365 and 366, October 1939.

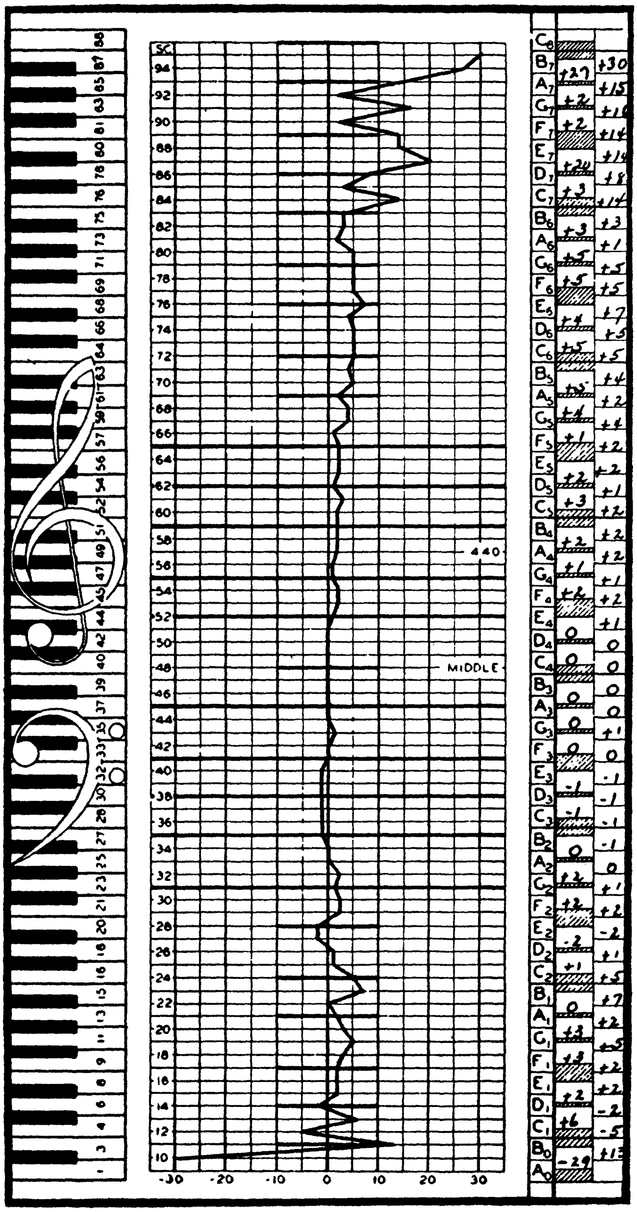

Fig. 6

is similarly marked to its left. The broken line shown in the figure joins all these points in turn. The waggles in it therefore indicate changing deviations from equal temperament. The numbers marked at the foot of the figure give the measure of these deviations in *cents*, a cent being a small unit used to measure the relation between the rates of two vibrations. To give some idea of the size of this unit it may be added that the equally tempered fifth should be 2 cents flatter than the perfect fifth which is the objective of the violinist in tuning his instrument. The deviations shown are therefore of the same order as those deviations from true intonation which are implied in equal temperament. The actual deviations, in cents, for each key of the piano have been entered by hand in the columns on the right-hand side. The deviations in the top and bottom octaves, which are hard to tune, are of little significance for present purposes.

The tuning recorded in Fig. 6 was specially selected as a particularly close approximation to equal temperament by a skilled tuner ; and for the selection of this record and for permission to reproduce it, the writer desires to express his indebtedness to Dr. Robert Young, of the firm of C. G. Conn Ltd., Elkhart, Indiana, U.S.A., the makers of the Chromatic Stroboscope. This record shows surprisingly good tuning, of a Steinway piano : records of other tunings show substantially greater deviation and a more waggly line, one of the less accurate ones constantly showing fluctuations by 5 cents or more, though the tuning it represents would be accepted as adequate. Not all tuners are equally skilled, and some pianos are harder to tune than others. An enharmonic change, which is very perceptible to the sensitive ear of the violinist, would theoretically call for an alteration of intonation by some 20 cents.

When the " theoretician " assures us that composers or artists think or play, in any exact sense, in equal temperament we are entitled to ask him to explain, scientifically, how they do it. If the piano tuner does not succeed in attaining a perfect equal temperament, how can the artist, playing a momentary note on an instrument of free intonation estimate *exactly* a dissonance which, as Helmholtz showed, must lack definition ? The " theoretician " may be referred to Hauptmann's comments :[16]

> Do you know that Spohr maintains that the singer should learn intonation from a piano in equal temperament ?— !— ?— :— ; what marks of admiration shall I use ? The fitting exclamations have yet to be invented. . . . And why should the singer cultivate

[16] ' Letters of a Leipzig Cantor ', Eng. trans. (Novello), Vol. I, p. 150.

> temperament? . . . Thanks to the indestructibility of natural organization *it cannot be learnt.* [The italics are the present writer's.]

And if the " theoretician " replies " well, of course, I don't mean *exactly* ", has he not conceded his whole case? For that admits a flexibility of intonation in the musical scale of an instrument with free intonation. The artist whose sensitive ear becomes conscious of the dissonance of a mistuned interval will use enharmonic change wherever it is needed to enable him to hear his intervals " in tune ".

The author of the article on 'The Schoenberg Concept' [17] in the issue of this journal for April 1939 was troubled by the difficulty of reconciling two truths alleged by the " theoretician ", " the chord of nature " and the handicap of equal temperament under which all occidental music has laboured since Bach's time. Those of us who have encountered this difficulty, and found that both truths are imaginary, will sympathize with him; and any resentment we may have against " theoreticians " for misleading honest musicians will be intensified. The outstanding feature of temperament is, not the precise degree of mistuning implied in any particular system, but the fact that it postulates a *rigid* intonation. The idea that Bach, of all people, elected to compose in such an intonation has only to be put into words to be dismissed as untenable. Mr. Noel Heath Taylor tells us that, in reply to a question, Schoenberg said, with a shrug: " Twelve-tone equal temperament is practical. There is no other popular medium available to the composer to-day ". No one will quarrel with the natural meaning of that statement; but the answer we want is that to the next question: " Do you consider that modern composers think, and that their music should be played, with a rigidly fixed intonation? " There is a quotation at the end of the article which suggests one reply that Schoenberg might make: " The criterion for the acceptance or rejection of dissonances is not that of their beauty, but rather only their perceptibility ". Exactly! What matters is the intonation we hear, the product of aural perception, not the vibrations we listen to, which determine a physical tuning but are only a first approximation, which may or may not be infinitesimally close, to the intonation we hear. Here, at any rate, Schoenberg's theory and practice find a common factor in scientific truth.

On the other hand the " chord of nature " is a scientific misconception which is at least a hundred years behind the times.

[17] 'Music & Letters', Vol. XX, No. 2, p. 184, 'The Schoenberg Concept', by Noel Heath Taylor.

Experiment taught the Greeks that consonances were produced by vibrating strings whose lengths had simple ratios—1:2 for the octave and 2:3 for the fifth. For over 2,000 years this relation between consonance and whole number was a puzzle. Before Rameau (1683–1764) no one found the right approach to the only explanation we can offer to-day. It was Rameau who observed that the first, third and fifth of the harmonic vibrations of a string, with suitable octave transpositions, gave all the "inversions" of the major triad. Rameau's observation, and the theory about *générateurs* which he based on it, were set out lucidly and logically by a distinguished physicist and mathematician, d'Alembert (1717–1783). At the end of Part II of 'Sensations of Tone'[18] Helmholtz gives an interesting review of Rameau's attempt to find a *natural* explanation of harmony. He writes :

> No one who considers the great perfection and suitability of all organic arrangements in the human body would deny that when the existence of such natural relations have been proved as Rameau discovered between the tones of the major triad they ought to be most carefully considered, *at least as the starting points for further research.* [The italics are the present writer's.]
>
> . . . .
>
> This attempt of Rameau and d'Alembert is historically of great importance, in so far as the theory of consonance was thus for the first time shifted from metaphysical to physical ground. It is astonishing what these two thinkers effected with the scanty materials at their command. . . . If I have been able to present something more complete, I owe it merely to the circumstance that I had at command a large mass of preliminary physical results, which had accumulated in the century which has since elapsed.

This is too modest a claim for the revolution Helmholtz effected in musical theory. He, in turn, shifted it from a physical to a physiological basis, by explaining how the overtones of a musical instrument enable our ears to distinguish between consonance and dissonance ;[19] in short, how we tell whether two notes are in tune and why intervals differ in definition. This is a far cry from Rameau ; and the passage from 'Sensations of Tone', quoted above, also records facts, evident to d'Alembert more than 150 years ago, to which the "theoretician" closes his eyes :[18]

[18] 'Sensations of Tone', Eng. trans. of 1875, p. 352.

[19] Not to be confused with concord and discord (wherever the musical idea of the time may draw the separating line). The 6–3 concord D—F—B is an acoustical dissonance, while the major 6–4, which was a discord in the polyphonic period and the next two centuries, is acoustically the most consonant triad.

> No one knew better than d'Alembert himself the missing links of this system. Hence in the preface to his book he especially guards himself against the expression : " Demonstration of the Principle of Harmony ", which Rameau had used. He declares that so far as he himself is concerned, he meant only to give a well-connected and consistent account of all the laws of the theory of harmony, by deriving them from a single fundamental fact, the existence of upper partial tones and harmonics, *which he assumes* [the italics are the present writer's] without further enquiry respecting its source. He consequently limits himself to proving the *naturalness* of the major and minor triads. He does not mention beats, the real source of distinction between consonance and dissonance.

Others, however, lacked d'Alembert's accuracy of thought. As Sir Donald Tovey observes :[20]

> In England Rameau's doctrine raged unchecked by taste and common sense, and culminated in Dr. Day's famous application of homœopathy to the art of music.

The " theoretician " who still derives his scale and his harmony *directly* from the harmonic overtones of musical instruments neglects all that science has discovered about " hearing " since Rameau's day. The very words " chord of nature " are misleading. The harmonic overtones of a musical instrument are pure tones.[21] If a group of them, produced electrically in the laboratory, are sounded together we do not hear a chord. Harvey Fletcher has shown[22] that if four consecutive upper partial tones are sounded together what we hear is a musical tone of the pitch of the fundamental, though that is lacking in the physical vibrations in the air. Ellis's " duodenation "[23] would lead musical composition to retrace its steps to Handel's day. Joseph Yasser's speculations in ' A Theory of Evolving Tonality ' have at least the merit that they are informed by a true musical conception, that of a living and constantly changing art : he produces a most elaborate edifice, but its foundations rest in quicksand, for he derives the hexad of his supra-diatonic scale, its " common chord ", from the eighth, ninth, tenth, eleventh, thirteenth and fourteenth partial tones of a musical instrument. It would be instructive if we could persuade some physicist to sound pure tones of these pitches, simultaneously, and observe what is heard. In fact, however, only the merest traces, if any, of the vibrations corresponding to these high partial tones are to be detected, by laboratory analysis, in many of the complex physical vibrations in the air which produce the tones

(20) ' Encyclopaedia Britannica ', 14th ed. (article ' Harmony ').
(21) ' Music & Letters ', Vol. XX, p. 368, October 1939.
(22) ' J. Acoust. Soc. Amer.', 1934, 6, 67.
(23) ' Music & Letters ', Vol. XIX, p. 446, October 1938.

we perceive as the sounds of musical instruments. The normal human ear cannot detect them. If future composers should ever develop the scale in the direction Yasser indicates, its intervals will depend, as Schoenberg would say and as he himself recognizes, on their perceptibility, and not *directly* on a series of high harmonic overtones such as are often lacking from a musical sound.

The use of the word " chord " suggests to the musician a group of notes played on musical instruments. But that is something quite different from the supposed " chord of nature ", for each of the " notes " of musical instruments contains its own overtones which give it definition and therefore individuality. Were there any truth in the conception of the " chord of nature ", using the words in their plain meaning, composers would long ago have given up writing for anything so harsh and crude as the orchestra would then be. Their genius would have impelled them to explore, instead, the nebulous beauties of a consort of ocarinas, for the note of the ocarina is a practically pure tone.

The " theoretician " is not entitled to stop just where he chooses in the application of his theory. All its logical implications must be explored. Should that exploration prove too much his theory stands self-condemned, as Helmholtz pointed out. The fever of Rameau's doctrine still rages ; all we can do is to prevent the infection from spreading. Helmholtz told us that " we must distinguish carefully between composers and theoreticians [*musikalischen Theoretikern*]".[24] Equally necessary is it to distinguish between men of science and " theoreticians ". The notion that harmonic tissue is derived *directly* from the harmonic overtones of a musical instrument, and its corollaries, a physical basis for music and a scale with fixed intonation, are the peculiar characteristics of the " theoretician ". We may use them to identify him (and his victims), just as we tell the leopard by his spots.

[24] ' Sensations of Tone ', Eng. trans. of 1875, p. 345, and ' Music & Letters ', Vol. XIX, p. 443, October 1938. "Theoreticians" neglected the evidence of the composer's ears.